



Design and development of a motor operated oil palm crusher for smallholder growers in Bangladesh

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Abstract

At present oil palm growers are facing problem to extract crude palm oil in Bangladesh. Processing of palm oil categorized into various forms but basic processing stages are essentially the same including harvesting, sterilization, bunch stripping, digestion, crushing, clarification and drying. Extracting of palm oil is very difficult by traditional method and oil recovery rate is very low. Although mechanical processing is costly but produces good quality Crude Palm Oil (CPO) and oil recovery rate is high. An electric motor operated oil palm crusher was designed and developed and tested in laboratory under the Department of Farm Power and Machinery, Bangladesh Agricultural University, Mymensingh for processing of crude palm oil from fresh fruit bunch. The crusher was designed by using Auto-Cad software. It was fabricated according to design parameters. The major parts of the crusher were screw shaft, cylinder, hopper, hollow bars, pressure case cap, jamnut and frame which were fabricated by mild steel (MS), ball bearing, gear and pinion, line and idle shaft and spring were fabricated by carbon steel (CS) whereas driver and driven pulley were fabricated by cast iron (CI). Crusher was mounted on the frame. A 9 hp electric motor was used as a power source. Crusher was tested after fabrication and 3000 gm fresh fruits were used. About 700 gm crude palm oil, 800 gm oil cake, 1400 gm skum were collected from 2700 gm pretreated fruits. The crushing capacity and crude oil percentage of the crusher was 6.49 kg/hr and 25.93%, respectively. Rotating speed of screw was 40 rpm for smooth running. The weight of crusher was only 70 kg which is easy to operate by single person. The developed oil palm crusher may fulfill the demand of smallholder growers to extract oil from fresh fruit bunches.

Key words: Palm oil, oil palm crusher, electric motor

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Introduction

Palm oil is one of the two most important vegetable oils in the world's oil and fats market following soybean (Hartley, 1988). Oil palm has been cultivated from the ancient times in Africa. The oil palm fruit produces two distinct oils which are palm oil and palm kernel oil. Palm oil is obtained from the mesocarp while palm kernel oil is obtained from the seed or

kernel. Palm oil is used mainly for the production of margarine and compounds in cooking fats and oils and also for the production of candles, detergents, soap and cosmetic products. Bangladesh is deficit in oils and fats since long. It produces only 10 percent of its requirement. At present, annual requirement of oil and fats in Bangladesh is about 2.30 million tons, of which,

on an average, about 63% shares belongs to palm oil and average annual import quantity of palm oil is about 1 million tons which is about 66% of total import of oils and fats (Alam, 2017). Though oil palm is not a traditional oil crop/plant in our country but to meet up the demand of palm oil, cultivation of oil palm is introduced in our country since 1978 through the import of seedlings from Nigeria and Malaysia.

The standard crude oil percentage of oil palm is 26-27 % (FAO, 2002). In palm oil mill (POM), oil palm fresh fruit bunches (FFB) are processed to produce crude palm oil (CPO). Palm fiber, empty fruit bunches, sludge, decanter cake and palm nuts are produced as byproducts. The nut is usually collected after the removal of the mesocarp fiber, and the kernel inside the nut is separated from the nut's shell for subsequent oil extraction. The shell can be utilized as fuel, used in the production of activated carbon for waste water treatment, and used in analytical applications. The production of palm kernel starts with the cracking of palm nuts using a palm nutcracker to produce a cracked mixture of palm kernel and palm shell. Subsequently, the separation of shell and kernel from the cracked mixture is performed using a combination of dry and wet separation systems. Over the years, extracting and expression of oil from oil seeds involve a wide range of traditional, chemical and mechanical processes (Kurki *et al.*, 2008). Most of the stages in the process are essentially the same, whether in a 60 t/h mill or a small-scale village process. Maycock, (1990) described the stages as i) Bunch sterilization with high pressure steam; this loosens the fruit from the bunch, and inactivates the endogenous lipase, and any micro-organisms, so that FFA build-up does not occur; ii) Bunch stripping, to separate fruit from bunch stalk and spikelet's, iii) Fruit digestion to pulverize and disrupt the mesocarp, with heating to aid oil extraction ;iv) Pressing or other treatment of the digested fruit to extract the oil; v) Separation, clarifying and drying the oil, vi) Separation of nuts from fibre, vii) Nut drying, grading and cracking; viii) Separating kernels from shell and ix) Kernel drying and packing. Onyeka *et al.*

(2002) investigated the best traditional palm oil extraction method practiced in Eastern Nigeria. Results showed that Oil from Sterilized Pressure Extraction Method (SPM) had the lowest (2.5%) free fatty acid (FFA) content while the Fermented. Akinoso *et al.* (2011) investigated that compressive stress, feeding rate and rotational speed of the expeller Influences the quality of expressed palm kernel oil. The lowest value of FFA content (1.09%) was produced at 10 Mpa compressive stress; 50 kg/h feeding rate and 110 rpm revolving worm speed. Optimum processing condition was achieved at compressive stress of 18.3 Mpa, 61.1 kg/h feeding rate and 76.7 rpm revolving worm speed. Amata and Ozuor (2013) conducted a research for comparing the quality of crude palm oil (CPO) produced by three different methods of oil palm processing in Delta North Agricultural Zone, which includes the scientific method, the semi-scientific method and the traditional method. Parameters studied to assess quality were free fatty acid (FFA) content, peroxide value and the carotene content. He also observed significant differences in per-oxide value except free FFA content and the carotene content. FAO (2002) founded that palm fruit contains about 56 percent oil (25 percent on a fresh fruit bunch basis) which is edible with no known toxins. It is thus suitable for small-scale processing. Hydraulic presses are faster than spindle screw types and powered presses are faster than manual types. Some types of manual press require considerable effort to operate and do not alleviate drudgery. Traditional method of palm oil processing is time consuming, laborious, hazardous and inefficient resulting in the production of low quality oil. Oil extraction still remains a critical bottleneck particularly the level of small and medium scale processors in Nigeria (Owolarafe *et al.* 2002).

Nowadays, oil palm trees are spread all over the country. But oil palm growers are facing problems with processing of palm oil from fresh fruits bunch in Bangladesh. A palm oil processing mill has been established at Comilla in large capacities but not viable at this moment for less palm production. So, it is prime

need to create a facility for small holder growers to extract oil from those fresh fruit bunches. Therefore, it is necessary to design and develop a suitable motor operated oil palm crusher which will help greatly for oil palm growers and reduce dependency to import of palm oil.

Materials and Methods

Design consideration: The following factors were considered in the design of motor operated oil palm crusher.

- ✓ Simple in construction so that local manufacturers can easily fabricate it
- ✓ Optimum clearance between the shaft and cylinder
- ✓ Simple and easy adjustment
- ✓ Uniformity in feeding rate
- ✓ Easy to repair and maintain
- ✓ Easy to operate
- ✓ Easily portable
- ✓ Less repair and maintenance cost
- ✓ Suitable for operating by a single person and
- ✓ Low cost within the buying capacity of small and medium farmer.

The motor operated oil palm crusher was designed and drawing was done with the help of Auto-Cad software. Then the crusher was fabricated accordingly and finally tested at the Workshop of Farm Power and Machinery Department, BAU, Mymensingh.

Materials to fabricate the crusher: Materials required to construct the crusher were procured from the local market. The major materials required to fabricate the crusher were mild steel (MS) for screw shaft, cylinder, barrel, hopper, hollow bars, pressure case cap, jamnut, frame and carbon steel (CS) for bearing, gear and pinion, spring pulley and cast iron (CI) for idle and line shaft.

Fabrication of cylinder and hopper:

Cylinder: A cylinder was fabricated according to drawing as shown in Figure 1. Outside and inside

diameter of the cylinder were 85 and 68 mm, respectively. The total length of cylinder was 254 mm. The cylinder was mounted with a bearing casing and fixed to the frame. It was made of MS sheet.

Hopper: Hopper is the most important part of the crusher. The shape of the hopper was square. The top of the hopper was 114.3 mm X 114.3 mm. Feeding diameter of hopper was 63.5 mm. Details of cylinder and hopper are shown in Figure 1.

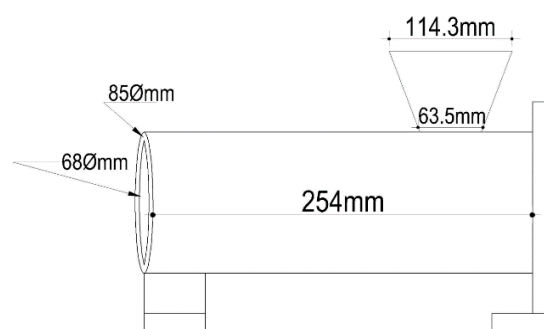


Figure 1. Details of cylinder and hopper.

Fabrication of barrel: The length of the barrel was 279.4mm (Figure 2). Outside diameter of barrel was 85 mm and inside was 68 mm. It was made of MS sheet.

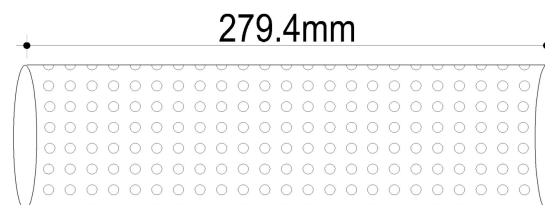


Figure 2. Details of barrel.

Fabrication of driven pulley: It was used for power transmission system and made of Cast Iron. Diameter of pulley is 254mm. It was adjusted to gear box. Hole diameter of pulley was 28mm. Drawing of the driven pulley are shown in Figure 3.

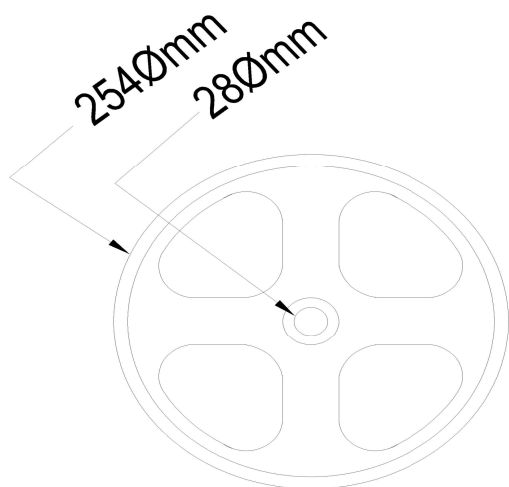


Figure 3. Details of driven pulley.

Driver pulley: Driver pulley was made of cast iron. Diameter of driver pulley was 10cm. It was connected to motor (Figure 4).



Figure 4. Photographic view of driver pulley.

Fabrication of gear and pinion: Gear and Pinion were used to reduce rotational speed. These were made of carbon steel. Diametral pitch of gear is 6, number of teeth in gear and pinion were 45 and 12, respectively. Drawing of gear and pinion are given in Figure 5 and 6, respectively.

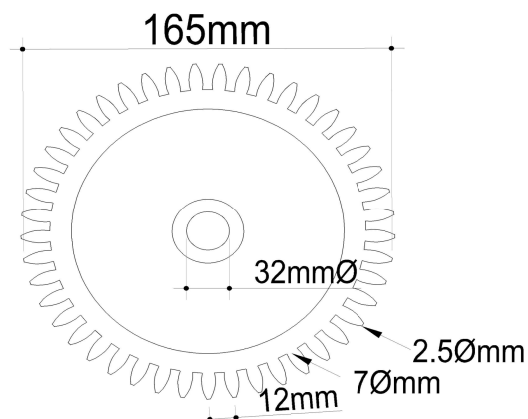


Figure 5. Details of gear.

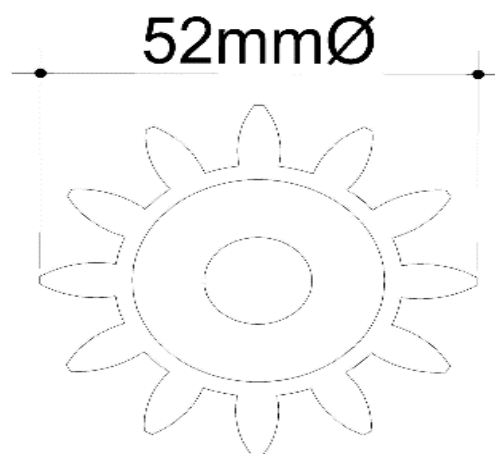


Figure 6. Details of pinion.

Fabrication of screw shaft: The screw shaft was fabricated by MS bar. Design of the screw shaft shown in Figure 7. The total length of the screw shaft was 939.8 mm. The length of helical screw portion was 533.4 mm. The diameter of helical screw shaft was 66 mm. The length of small helical screw portion was 203.2 mm and diameter of small shaft was 38mm. The root diameter of the screw was used for increasing high pressure.

Fabrication of idle and line shaft: Idle shaft and Line shaft both were made of carbon steel. Two bearing were connected with idle shaft. One pinion and gear were connected with line shaft (Figure 8).

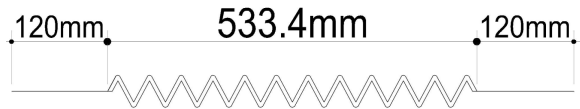


Figure 7. Details of screw shaft.



Figure 8. Idle shaft and line shaft.

Fabrication of spring and driver pulley:

Spring: The diameter and length of spring were 62mm and 110 mm, respectively. It was made of carbon steel as shown in Figure 9.

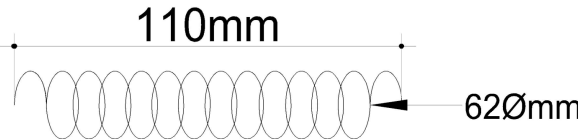


Figure 9. Details of spring.

Fabrication of frame: Frame was made of MS angle bar as shown in Figure 10. The crusher was mounted on frame.



Figure 10. Photographic view of frame.

Working principle of the motor operated oil palm crusher: First pretreated fresh fruit bunch was put in the hopper. When the round screw shaft rotates then pretreated fresh fruit bunch enters into the chamber from the hopper and then moves forward by the rotation of pressing screw and was pressed. Under the high-pressure condition in the chamber, friction creates between material and screw thread and internal friction creates among the materials and particles. On the other hand, root diameter of the pressing screw varies from larger end to the smaller end. Hence, when rotating, it not only pushes materials moving forwards but also turns those outwards as well. Meanwhile, materials adjacent to the screw will rotate along with screw's rotation, causing every particle inside the chamber to possess different speed. Therefore, relative movement among materials creates heat which is necessary during processing because of helping protein change property, damage colloid, and increase plasticity.

Performance test of the crusher: Pretreated 2700 gm fresh fruit was taken in the hopper, oil collector pan was fixed under the oil discharge slot. Then a stopwatch was taken for determining the operating time. After that, started to rotate the handle for crushing the fruit inside the pressure case cylinder and stopwatch was started at that time. After some time, cylinder was loaded by the fruits. Gradually high pressure was developed in the cylinder for that reason oil extract from the pressed fruits and oil was moving to the discharge slot. Crude oil was collected by the collecting pan and total operating time was recorded.

Determination of crushing capacity (kg/hr) of the oil palm crusher: Total amount of fruits are crushed by the crusher per unit time is the crushing capacity (kg/hr) of the oil palm crusher. Before crushing, fruits were weighted and time counted by the stopwatch. So, the Crushing capacity = W/T ; Where, W = Weight of fruits, kg and T = Total crushing time, hr.

Measurement of rpm of the screw shaft of the oil palm crusher: At first, the diameter of driven and driver pulley were measured. Then the revolution per

min (RPM) of driver pulley was determined. Using this data, the RPM of driven pulley was calculated. Then the number of teeth of gear and pinion were determined. At last the RPM of motorized of oil palm crusher was calculated to get average rpm of the oil

palm crusher by the formula: $D_2/D_1=N_1/N_2=T_2/T_1$, Where, N= RPM of driven and driver pulley, T= Number of Teeth gear and pinion and D= Diameter of driven and driver pulley (Figure 11).

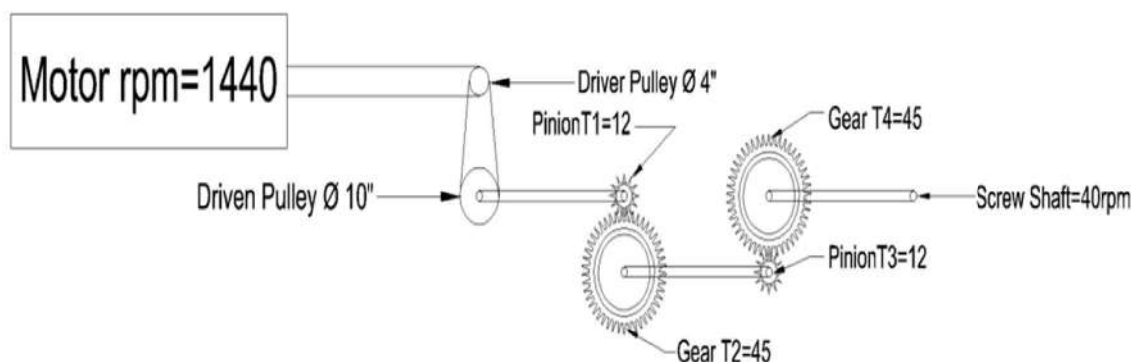


Figure 11. RPM measurement of shaft.

Determination of amount of crude palm oil per kg of fruits: Amount of crude palm oil was divided by the amount of fruits thus obtained the amount of crude palm oil per kg of fruits.

Results and Discussion

Development of motor operated oil palm crusher:

The motor operated crusher machine was fabricated according to the design parameter. The clearance between screw shaft and pressure case cylinder was kept 2 mm to avoid friction. The weight of the crusher was only 70 kg.

Different parts of crusher are shown in (Figure 12). Isometric and pictorial views of the crusher are shown in Figure 13 and 14, respectively.

The specification of the crusher: Detailed specification of the crusher is given in Table 1.

Screw shaft rpm of the oil palm crusher: Screw shaft rpm of the oil palm crusher was reduced from 1440 to 40 by using one set of belt-pulley and two set of gear.

Table 1. Specification of the motor operated oil palm crusher.

Particulars	Description
1 Name	Motor operated oil palm crusher
2 Electric motor	9 hp , RPM 1440
3 Power transmission from motor	V-belt (B-type)
4 Weight of the machine	70kg
5 No. of Cylinder and Barrel	One and one, 19 cm
6 Gear	Pitch dia. 19cm, no. of teeth 45
7 Pinion	Pitch dia. 4.5cm, no. of teeth 12
8 Pulley s(Driver and driven)	10cm and 25.4cm
9 Bearing	(UCP206 and Ball)
10 No. of hopper	One
11 Feeding system	Rotating screw shaft
12 Recommended speed	40 rpm
13 Crushing capacity	6.49 kg/hr

Step 1: rpm of the motor = 1440

Step 2: rpm of the first shaft = $(4 * 1440)/10 = 576$

Step 3: rpm of the second shaft = $(12 * 576)/45 = 153.6$

Step 4: rpm of the crusher shaft = $(12 * 153)/45 = 40.8 = 40$ rpm

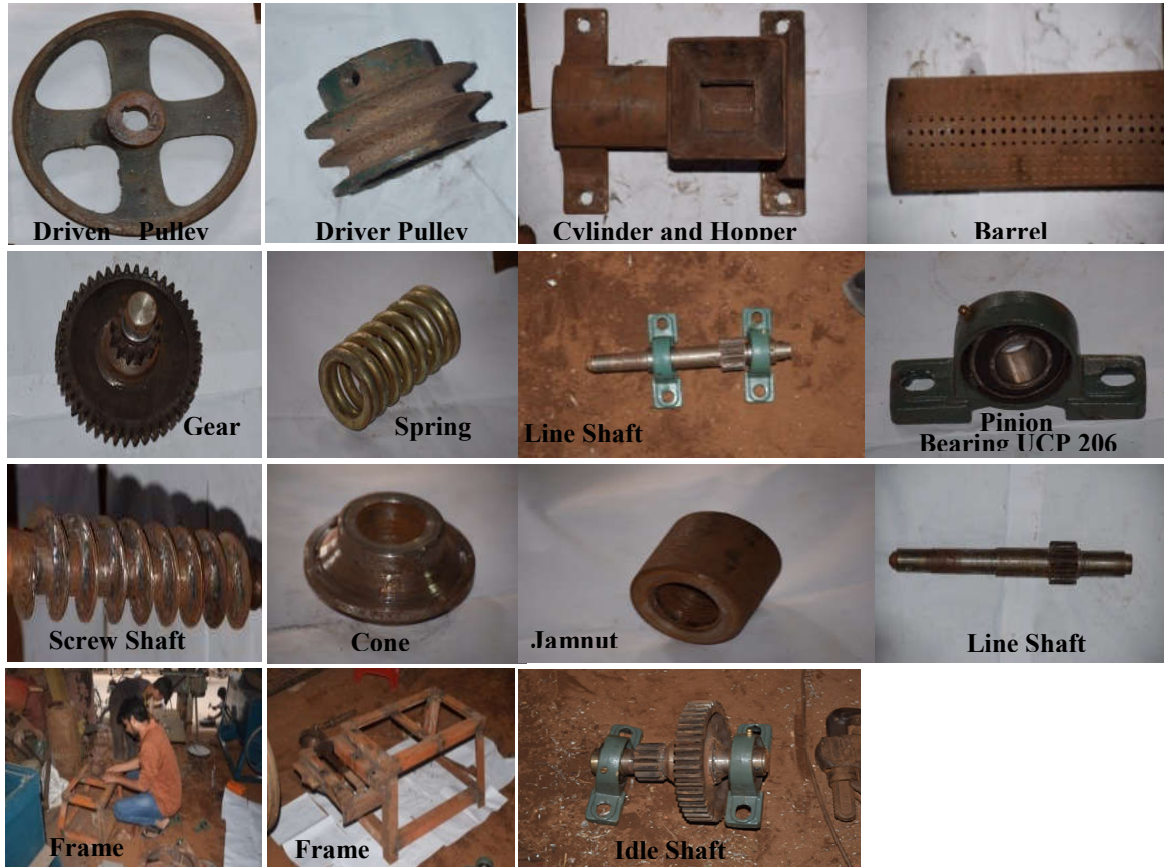


Figure 12. Different parts of oil palm crusher.

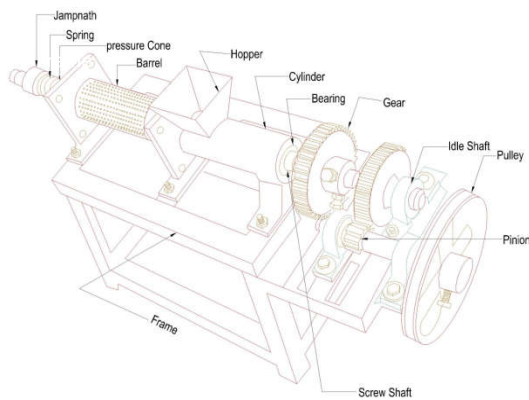


Figure 13. Isometric view of motor operated oil palm crusher.



Figure 14. Photographic view of oil palm crusher.

Amount of crude palm oil, skum, oil cake:

About 700 gm crude palm oil, 800 gm oil cake, 1400 gm skum were collected from 2700 gm pretreated fruit or 3000 gm fresh fruit as shown in Table 2.

Table 2. Amount of crude palm oil, skum, oil cake.

Serial no.	Component	Amount (gm)
1	Fresh fruit	3000
2	Pretreated FFB	2700
3	Oil cake	800
4	Skum/sediment	1400
5	Crude palm oil	700
6	Loss	100

Time taken for crushing 2700 gm pretreated fruit was 25 minutes. Total time needed to get 700 gm crude palm oil from 3000 gm fresh fruit bunch has shown in Table 3.

Table 3. Total time to get 700 gm crude palm oil from fresh fruits.

Serial no.	Component	Time (minute)
1.	Pretreatment	50
2.	Crushing operation	25
3.	Others	5
	Total time	1 hr and 20 minute

Crushing capacity and oil extraction rate of the crusher:

Pretreated 2700 gm fruit was crushed in 25 minute and was obtained 700 gm crude palm oil. So, the crushing capacity of the crusher was 6.49 kg/hr. Amount of crude palm oil was divided by the amount of pretreated fruit thus obtained the amount of crude palm oil per kg of pretreated fruit. After crushing operation 700 gm crude palm oil was extracted from 2700 gm pretreated fruit. So, the extraction oil (gm) per kg of pretreated fruit were obtained 259.26 gm/kg and the percentage of crude oil extraction was 25.93%.

Conclusions and Recommendations

A motor operated oil palm crusher was designed and fabricated using locally available materials. The weight of crusher is 70 kg which is easy to operate by single person. The crushing capacity of the crusher was 6.49kg/hr at a speed of 40 rpm and crude palm oil extraction percentage was 25.93%. Operation of the machine is very easy. It can fulfill the needs of small oil palm growers to extract crude oil from fresh fruit.

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